Unit 15

ELECTROSTATICS

Q. Show by experiment that same charges repel each other.

Ans. Electric charges are of two types.

(1) Positive charge.

(2) Negative charge.

EXPERIMENT-1:

Rub two glass rods with silk and suspend them horizontally in a line close to each other we will see that they will repel each other which shows that they have same charge.

EXPERIMENT-2:

Rub two ebonite rods with woolen cloth and suspend them horizontally closer to each other. We will see that these rods will repel each other. Since in both experiments glass rod is rubbed with silk cloth and ebonite rod rubbed with woolen cloth, so we are justified to assume that the charge on both rods would be of same kind.

Q. Write an experiment which shows that unlike charge attract each other.

EXPERIMENT-3:

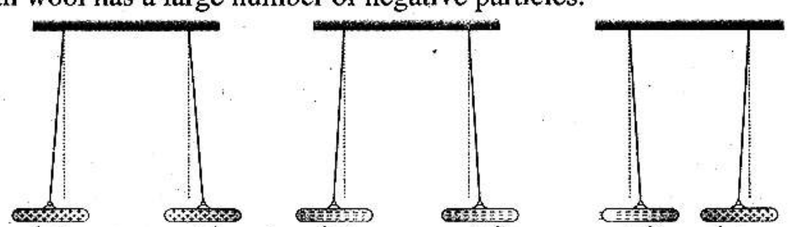
Now suspend a glass rod rubbed with silk near ebonite rod rubbed with wool, close to each other. This time these two rods will attract each other.

Result:

This shows that charges in this case are opposite to each other to cause attraction between the bodies. We also have result that charges on two rods are of two kinds. The charge on glass rod is positive. The charge on ebonite rod is negative. We can say that charges are of two types i.e positive charge and negative charge.

Role of Charged Particle:

The charge on glass and ebonite rod is infact due to presence of positive and negative charge particles. The glass rod rubbed with silk has a large number of positive particles while ebonite rod rubbed with wool has a large number of negative particles.



Two glass rods rubbed with silk repel each other.

Two ebonite rods rubbed with wool repel each other.

A glass rod rubbed with silk and an ebonite rod rubbed with wool attract each other.

Q. Write the structure of an atom.

STRUCTURE OF ATOM:

An atom consists of two parts.

(i) The nucleus (ii) The electrons

(i) The Nucleus:

The central part of an atom is nucleus, which has protons and neutrons. A proton carries positive charge while a neutron carries no charge.

(ii) The Electron:

The electrons revolve around the nucleus in various orbits and have negative charge.

Atom is neutral as a whole because the number of positive charge is equal to number of negative charge. Since there is force of attraction between positive and negative charge. Due to this force of attraction, the electrons move in their respective orbits, which they cannot leave.

But as the distance of orbit from the nucleus increases, the force of attraction decreases, so the electron in outermost orbit are under the action of weak nuclear force. Such electrons can easily be separated from their respective nuclear orbit.

Q. How is the charge produced on a body by Rubbing?

Ans. Charge on ebonite rod by rubbing:

When an ebonite rod is rubbed with woolen, the loosely bounded electron in the wool are transferred to ebonite rod. So due to abundance of electron negative charge is developed on ebonite rod.

Charge on glass rod by rubbing

When a glass rod is rubbed with silk, the loosely bounded electron of glass are transferred to silk due to which number of electrons in the glass rod decrease. Therefore glass rod is positively charged.

Conclusion:

(1) Solid bodies are charged due to transfer of electrons.

(2) If electrons are transferred to the body, then it is negatively charge and if electrons leave it. It gets positive charge.

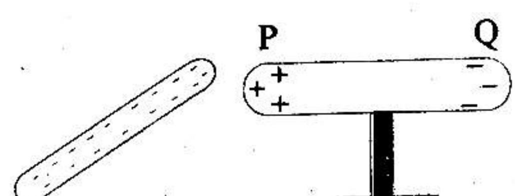
(3) In metallic substance, electrons in last orbit are so loosely bounded, that their motion is no longer confined in the orbit, so they can freely move through the whole of the metal. These are called **free electrons**.

Q: Explain the phenomenon of electrostatic induction.

Ans. "If in the presence of a charged body, an insulated conductor has like charges at one end and unlike charges at the other end then this is called the electrostatic induction."

EXPERIMENT:

A metallic body PQ is placed on insulated stand. When negatively charged ebonite rod is brought near its end P, it shows the presence of negative charge at the end Q and positive charge at the end P when the ebonite rod is removed the charge on PQ also vanishes. This shows that charge on PQ appears only in the presence of charged ebonite rod.



Since in this phenomenon all charges remain static that is why it is known as electrostatics.

EXPLANATION:

This phenomenon can be explained in term of free electrons. The negative charge on ebonite rod repels the free electrons to the end Q.

Hence, the end Q gets negative charge and deficiency of electron at P shows the positive charge. The quantity of negative charge at Q is equal to the quantity of positive charge appearing at P. when ebonite rod is removed the repelling force on free electrons disappear and free electrons spread uniformly on whole conductor. Therefore the deficiency of electrons at the end P and the excess of electrons at the end Q no longer exist.

Q: Describe a Gold Leaf Electroscope by using this how we can find the:

(i) Presence of Charge on a Body

(ii) The nature of charge present on body.

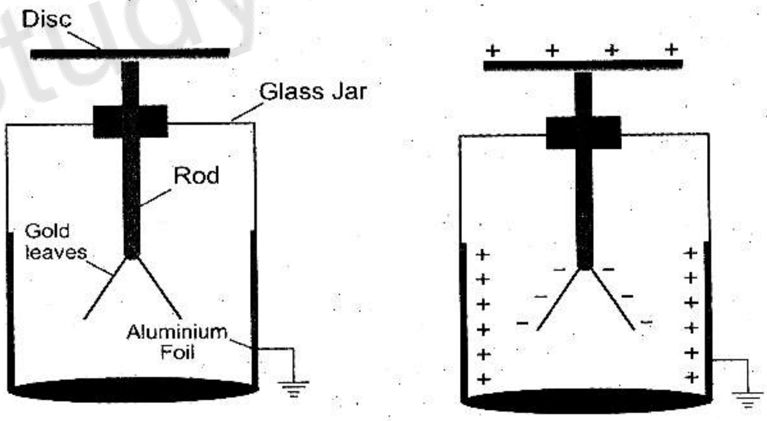
(iii) Whether a body is insulator or Conductor?

Ans. <u>ELECTROSCOPE:</u>

"It is an instrument used for detecting and testing the nature of charge on a body".

<u>CONSTRUCTION:</u>

It consists of brass rod, which has a brass disc connected to its upper end and two very thin gold leaves attached at its lower end. By the help of cork this assembly is mounted inside a glass jar with brass disc projecting outside. A thin aluminum foil is pasted on the lower portion of the inner surface of jar. Generally this foil is grounded by means of copper wire.



Electroscope

The leaves diverge due to the presence of similar charge.

Effects of Charges:

When any charge is transferred to electroscope, it spreads on the disc and the leaves. Due to force of repulsion between similar charges on the leaves, they diverge. The divergence of leaves depends upon the quantity of charge on the leaves.

Presence of charge on a body

In order to detect the charge on the body. Bring the charged body near the disc of an uncharged electroscope. If body is charged leaves of the electroscope will diverge, otherwise it would remain in their normal position.

The divergence in the leaves of the electroscope due to the presence of a charged body is due to electrostatic induction. Suppose negative charge brought near to the disc. Due to induction positive charge will appear on the disc and negative charge on the leaves. Due to presence of negative charge, the leaves will diverge.

Nature of charge:

In order to detect the nature of charge on a charged body, the electroscope will have to first charged either with positive charge or with negative charge. By touching the disc with negative charged body and positive charged body. The disc will be positive or negatively charge.

In this process some charge is transferred to the disc and the leaves of the electroscope.

After charging, the electroscope, bring the body under test near the disc of electroscope.

If divergence of leaves increases, the body has the same kind of charge as on electroscope. On the other hand, if divergence decreases then charge on the body is opposite to the kind present on electroscope.

Distinguish between insulator and a conductor:

Touch the disc of charged electroscope with body under test. If the leaves collapse from their diverge position, then body is a good conductor.

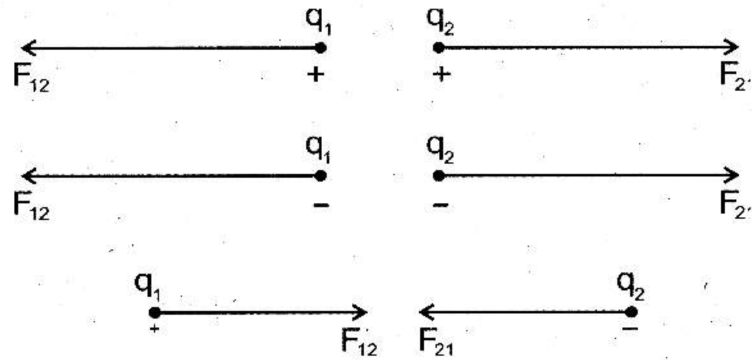
If there is no change in divergence of the leaves then the body is an insulator.

A gradual collapse will indicate that body is not a good conductor or insulator.

Q: Explain Coulomb's Law and Write Mathematical Form. **(L. B '08, 09)**

Ans. This law was put forward by French scientist Charles Coulomb.

"The force of attraction or repulsion between two charged bodies is directly proportional to the product of the quantity of charge on them, and inversely proportional to the square of the distance between them."



POINT CHARGE:

If the distance between two charges is much greater as compared to their size then these bodies are considered as point charge.

F_{12} is the force, which charge q_1 experiences due to q_2. F_{21} is the force on q_2 due to q_1. These forces act along the line joining the two point charges.

If the charges are opposite, they have attractive force between them and if the charges are same, they will repel each other.

F_{12} and F_{21} have same magnitudes but opposite in direction.

MATHEMATICAL FORM:

If q_1 and q_2 are two point charges, separated by distance 'r' then according to Coulomb's Law.

$$F \propto q_1 q_2 \text{ -------------------- } (1)$$

and $$F \propto \frac{1}{r^2} \text{ ----------------------- } (2)$$

by combining (1) and (2)

$$F \propto \frac{q_1 q_2}{r^2}$$

$$F = \frac{K q_1 q_2}{r^2}$$

Where 'k' is constant and its value depends upon medium between two charges and system of unit in which F, q and 'r' are measured.

In SI, If the medium between the two charges in space or air then in this case the value of k will be $9 \times 10^9 \, Nm^2 C^{-2}$.

In order to show the dependence of k upon the medium, usually it is expressed in terms of a property of medium known as permitivity. In case of free space it is represented by ε_o. The relation between k and ε_o is given by.

$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \; Nm^2 C^{-2}$$

By substituting the value of k

$$F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \text{ ------------------ } (1)$$

By using Eq. (1), we can find the force between two point charges placed in free space or air.

Q: What is meant by electric field and electric field intensity?

Ans. Electric Field:

The electric field of a charge is a region of space surrounding it, in which a charge can feel its electrostatic effect in the form of force.

Explanation:

Consider a positive charge Q and bring a charge q at a distance 'r'. The q will experience a force. According to coulomb's law, the value of this force will depend upon distance between two charges.

If charge 'q' is moved away from Q, this force will decrease till a certain distance, the force would practically reduce to zero.

Electric Field Intensity:

The strength of the field at any point is called electric intensity (E).

Mathematical form:

In order to calculate the value of electric intensity at a point in the field. We place a test charge q at that point. If **'F'** is the force acting on it, then **E** is given by:

$$\mathbf{E} = \frac{\mathbf{F}}{q}$$

$$\mathbf{F} = q\mathbf{E}$$

Intensity may be defined as **force acting on unit positive charge is called electric field intensity.**

UNIT:

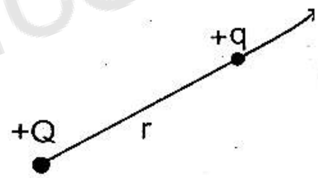
Its unit is N/C. or Nc^{-1}. It is a vector quantity.

Direction:

Its direction, is same as that of force acting on positive test charge. If the charge is free, it will move in the direction of electric intensity. In case of negative charge, F = qE is, therefore, negative charge will move in a direction opposite to electric intensity.

Q: To Find electric intensity at point due to positive charge Q in the field:

To find electric intensity due to point charge Q, suppose a charge is located at a distance 'r' from the +Q, at which electric intensity is to be determined. We will place a charge q at this point.



The coulomb force acting on the charge is

$$F = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}$$

$$E = \frac{F}{q}$$

By putting the value of F.

$$E = \frac{\frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}}{q} = \frac{1}{4\pi\epsilon_0}.\frac{Qq}{r^2 q}$$

$$E = \frac{1}{4\pi\epsilon_0}.\frac{Q}{r^2}$$

Electric intensity is directed away from the charge Q along the line joining the two charges.

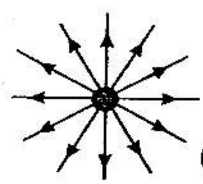
Q: What is electric lines of forces? Explain.

Ans. The direction of electric intensity in an electric field can also determined by drawing lines. These lines are called electric lines of forces. **OR**

The path alongwith a unit positive charge will move in an electric field is called electric lines of force.

Origin:

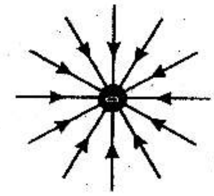
These lines of force originate from positive charge and terminate at negative charge, and are such that the tangent drawn at various points on a line the direction of electric intensity at these points.


(a)

The tangents at points A,B, C, D indicate the direction of intensity. If positive charge is placed at these points, it will move in the direction of these tangents.

Lines of force due to positive charge:

Due to electrostatic induction positive induce negative charge on the surrounding body, so the lines of forces end at these charges induced negative charge has not shown. Similarly figure (b) also does not indicate the oppositely induced charge.

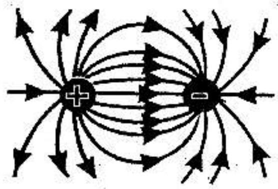


(b)

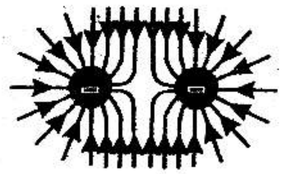
Strength of field:

The number of lines of forces is related to the strength of the field.

(1) The lines are close together in the region where the field is strong.



(c)



(d)

and far apart in the weaker region of the field.

Therefore by just seeing the line of force, we can get information about its magnitude and direction of electric field intensity.

Q. What do you mean by Electric Potential? Explain.

Ans. **<u>ELECTRIC POTENTIAL:</u>**

The potential at any point in the field is defined as "the potential energy of a unit positive charge placed at that point which is equal to the amount of work done in bringing a unit positive charge from infinity to that point."

Mathematical Form:

If W is the amount of work done in bringing a test charge +q from infinity to a certain point in the field, the potential V at this point would be given by:

$$V = \frac{w}{q}$$

It is scalar quantity and its unit is volt.

Volt:

If potential energy of one coulomb charge at a point is one joule, then potential at that point is said to be one volt.

$$1\ V = \frac{1\ J}{1\ C}$$

<u>Behaviour of positive charge in electric field:</u>

When a body is released in gravitational field it will move from higher potential to lower potential similarly when a charge 'q' is left free in an electric field, it will move from higher potential A to lower potential B.

Energy supplied by charge:

If the potential of the point 'A' is V_A and of B is V_B then potential energy of charge will be qV_A and qV_B. When charge move from A to B. The difference of these potential energies $qV_A - qV_B$ is supplied by the charge as it moves from A to B.

$$E = q(V_A - V_B)$$

This energy can be utilized by us in doing different kinds of work.

Potential Difference:

If q is equal to one coulomb, then the potential difference between two points gets equal to the energy supplied by the charge.

Definition:

"The potential difference between two points can be defined as the energy supplied by a unit charge as it moves from one point to the other".

If q = 1 coulomb then

$$E = 1(V_A - V_B)$$

$$V_A - V_B = E$$

Thus the potential difference between two points can be defined as "The energy supplied by a unit charge as it moves from one point to another point, against the electric field."

Note:

When a positive charge is moved from lower potential to a point of higher potential, energy has to be supplied to it. When we release a negative charge in an electric field, then its behaviour is just the opposite. It will move freely from lower potential to higher potential and supplies us energy. When we move a negative charge from higher to lower potential we will have to supply energy by doing work on it.

Electron Volt:

The unit of energy is electron volt (ev) which is defined as

"The amount of energy supplied by an electron as it moves between two points having potential difference of one volt".

Charge on electron = $q = 1.6 \times 10^{-19}$ C

$$V_A - V_B = 1V$$

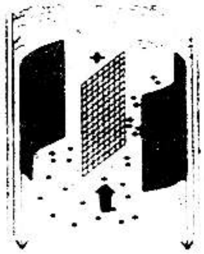
Then $$1 \text{ ev} = 1.6 \times 10^{-19} \text{ C} \times 1\text{V} = 1.6 \times 10^{-19} \text{ C} \times \frac{J}{C}$$

$$\mathbf{= 1.6 \times 10^{-19}\ J}$$

This is smaller unit of energy and this unit is used in atomic and nuclear physics.

Q. Describe the various practical applications of phenomenon of electrostatics.

Ans. Separation of smoke particles from gases:



Electrostatic phenomenon is used for separation of smoke and other particles from the gases coming out of the chimneys of factories. A wire gauze is used between two metallic plates, which are grounded. The wire gauze is highly positive charged. By electrostatic induction negative charges are induced on the inner surface of the metal plates when gases containing smoke passes through space surrounding positive charged wire gauze, then positive charge is produced on these particles. These positive

charged smoke particles are attracted by the plate due to negative charge. Hence these particles on reaching the plate are deposited there. In this way smoke and other particles are removed from the gases coming out of chimneys.

Electro-painting:

In automobile industry electro painting has acquired the status of a standard technology.

The body of the car is earthed when the particles of paint come out from the nozzle of the spray machine. They get a positive charge, when these positive charged particles reach near the body of car, they induce negative charge on its surface due to electrostatic induction. These negative charges attract the incoming positive charged paint particles. Hence a thin film of paint is formed on the surface of paint.

Advantages:

This method is cheap, efficient and effective. It needs less paint. This is widely used for painting of refrigerator, metallic furniture and other articles.

Q. What is meant by Capacitors and Capacitance?

Ans. **Capacitor:**

Capacitor is an electric device to store electric charge for a long period of time.

Construction:

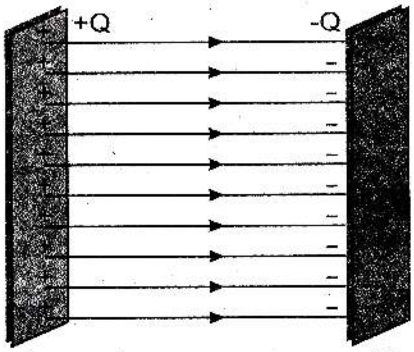
A simple capacitor consists of two parallel plates, which are separated with very small distances between them.

Working:

The medium between two places is air or sheet of some insulator. This medium is known as dielectric.

If positive charge Q is transferred to plate A due to induction it would induce –Q on inner surface of plate B and +Q on its outer plate.

There exists a force of attraction between charge +Q stored on the plate and –Q on inner surface of the plate. Due to force of attraction, the charges are bounded with plates and remains stored for a long period.



Di-electric the medium between the two plates is air or a sheet of some insulator. This medium is known as dielectric.

Due to presence of charge on plate a potential difference V is created between them which is directly proportional to charge Q given to plate.

$Q \propto V$

$Q = CV$

Where 'C' is the constant of proportionality and is called capacitance of the capacitor and its value depends upon size of conductor.

CAPACITANCE:

In charging the conductor some work has to be done due to which potential of the conductor rises and experiments show that charge on the conductor is directly proportional to its potential 'v'.

$Q \propto V$

$Q = CV$

Where C is a constant whose value depends upon the size of the conductor and is known as capacitance of the conductor.

If $V = 1$ volt

Then $Q = C$

i.e. capacitance of the conductor equal to the charge on plates, which raises the potential of conductor by 1 volts.

Unit:

The unit of capacitance is farad.

Farad:

It is the capacity of that conductor to the potential of which rises by one volt when one coulomb charge is given to it.

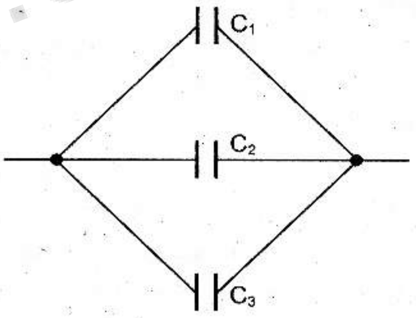
Q. Describe the characteristics and features of parallel combination.

Ans. Capacitors are widely used in various electronic circuits. They are joined together by two methods.

(1) Series combination (2) Parallel combination

Parallel Combination:

In this combination left plates of a capacitor are connected to a point and right plates to another point.



Characteristics:

(1) When capacitors are connected to a battery of voltage V the potential difference across each capacitor is 'V'.

(2) The battery supply charge to each capacitor and its quantity depends upon capacitance of capacitor in the circuit.

The charge on capacitor C_1 is

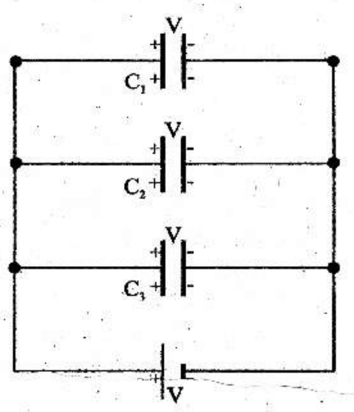
$Q_1 = C_1V$

The charge on capacitor C_2 is

$Q_2 = C_2V$

The charge on capacitor C_3 is

$Q_3 = C_3V$



Let Q is the total charge supplied by the battery.

Then $Q = Q_1 + Q_2 + Q_3$

$CV = C_1V + C_2V + C_3V$

$CV = V(C_1 + C_2 + C_3)$

$C = C_1 + C_2 + C_3$

(3) The parallel combination can be replaced by equivalent capacitor of capacitance C_e.

Then $C_e = C_1 + C_2 + C_3$

If 'n' capacitors are combined in parallel the equivalent capacitance of the combination is.

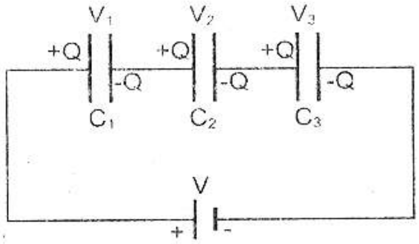
Then $C_e = C_1 + C_2 + C_3 + \text{-------------} + C_n$

The combination is used to increase the value of capacitance.

Series Combination:

In this combination capacitors are connected plate to plate right plate of one capacitor is connected to left plate of next capacitor. .

Characteristics:



(1) In this combination, the charge on each capacitor would be same. The battery supplies +Q to left plate on the capacitor C_1. Due to induction –Q charge is induced on left side and +Q to the left plate of capacitor C_2. This process goes on due to which each capacitor gets Q charge.

(2) The potential difference between the plates of each capacitor is according to its capacitor. The potential difference between plates of capacitor C_1, C_2 and C_3 are respectively.

$$V_1 = \frac{Q}{C_1}$$

$$V_2 = \frac{Q}{C_2}$$

$$V_3 = \frac{Q}{C_3}$$

The battery voltage is divided among various capacitor is:

$$V = V_1 + V_2 + V_3$$

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

The series combination in a circuit can be replaced by equivalent capacitance C_e.

$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

When n capacitors are connected in series then

$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \text{------------} + \frac{1}{C_n}$$

Capacitors connected in series decrease the value of capacitances.

Q. What are different types of capacitor? Give detail.

Ans. Capacitors are classified into various types depending upon their construction and nature, generally they are divided into two types.

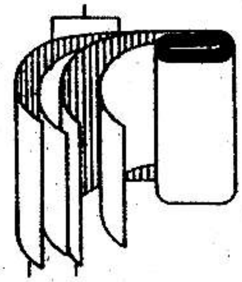
(1) Fixed Capacitors **(L. B '08)**

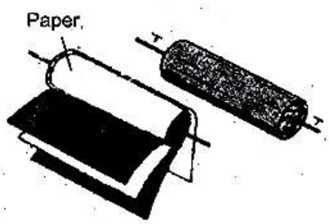
(2) Variable Capacitors

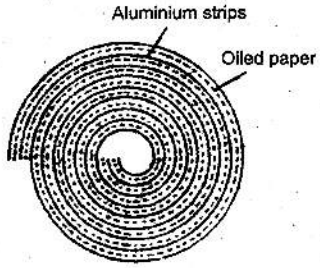
Fixed Capacitors:

If the plates of the capacitor are immovable, then such capacitors are called fixed capacitor. The capacitance of such capacitor cannot change.

Example is Paper Capacitor, mica capacitor.





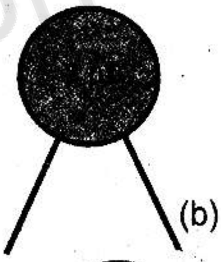


Construction:

Paper capacitors are cylindrical in shape. Generally oil or greased paper or thin plastic paper sheet is used as a dielectric between two aluminum foil which is rolled in cylinder and then enclosed in metallic cases.

Mica Capacitors:

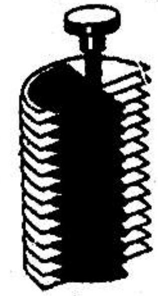
These capacitors are also the example of fixed capacitor.



Construction:

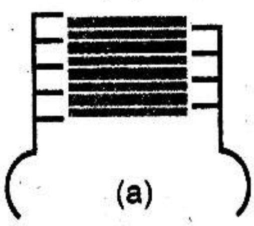
Mica is used as dielectric between two metal plates. For convenience and safety it is enclosed in a plastic case or in insulator. Wires are attached with plates projected out of the case for making connection.

To increase the capacitance large number of plates are piled up one over the other with layers of dielectric in between and alternate plates are connected with each other.



Variable Capacitors:

If in a parallel plate capacitor some arrangement is made so that the area of the plates facing each other can be changed, then it is called a variable capacitor.



It is usually a combination of many capacitors with air as dielectric. It consists of two sets of plates. One set remains static while the second one can rotate so the distance between the plates remains the same and they do not touch each other. The common area of the plates of the two sets, which faces each other, determines the value of the capacitance. Thus the capacitance of the capacitor can be increased or decreased by turning the rotatable plates in or out of the space between the static plates. Such capacitors are generally used for tuning in radio sets.

EXAMPLES

EXAMPLE 15.1

Two bodies are oppositely charged with 500μC and 100 μC. Find the force between the two charges if the distance between them in air is 0.5m.

Solution:

The given data is

$q_1 = 500\mu c = 500 \times 10^{-6} c$

$q_2 = 100\mu c = 500 \times 10^{-6} c$

$r = 0.5\ m$

Formula:

$$F = \frac{1}{4\pi\epsilon_o} \frac{q_1 q_2}{r^2}$$

Putting values, we get.

$$F = 9 \times 10^9 \times \frac{(500 \times 10^{-6}) \times (100 \times 10^{-6})}{(0.5)^2}$$

$$F = \frac{9\times10^9 \times10^2\times10^{-6}\, 10^2\times10^{-6}}{0.25}$$

$$= \frac{9\times10^9 \times5\times10^2\times10^{-6}\times10^2\times10^{-6}}{0.25}$$

$$= \frac{45\times10^{9+2-6+2-6}}{0.25}$$

$$= \frac{45\times10}{0.25}$$

$$= 1800N$$

$$\boxed{F = 1800\ N}$$

EXAMPLE 15.2

Two points P and Q are located at a distance of 5 cm and 20 cm respectively from a point charge of +10 μC. Find the magnitude of electric intensity at these point.

Solution:

Quantity of charge = Q = 10 μC = $10\times10^{-6}C$

Distance from the charge P = r_1 = 5cm = 0.05m

Distance from the charge Q = r_2 = 20cm = 0.2 cm

Electric intensity at P = E_1 = ?

Electric intensity at Q = E_2 = ?

Intensity at the distance r_1 = $E_1 = E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r_1^2}$

$$E_1 = \frac{9\times10^9\times10\times10^{-6}}{(0.05)^2}$$

$$= \frac{9\times10^{9+1-7}}{0.0025}$$

$$= \frac{9\times10^{9}}{0.0025}$$

$$= \boxed{3.6\times10^{7}\ NC^{-1}}$$

Electric intensity at the distance $r_2 = E_2 = E = \frac{1}{4\pi\epsilon_o}\frac{Q}{r_2^2}$

$$E_2 = \frac{9\times10^{9}\times10\times10^{-6}}{0.04}$$

$$E_2 = \frac{9\times10^{9+1-6}}{0.04}$$

$$E_2 = \frac{9\times10^{4}}{0.04}$$

$$E_2 = \boxed{2.25\times10^{6}\ NC^{-1}}\text{ Ans}$$

It can be seen that the magnitude of electric intensity decreases with the increase of distance.

EXAMPLE 15.3

The capacitance of a parallel plate capacitor is 100 pF. If the potential difference between its plates is 50 volts, find the quantity of charge on its plate.

Solution

The given data is

Potential difference = V = 50V

Capacitance = 100 PF

$= 100\times10^{-12}$ F

Charge = Q = ?

Formula:

$Q = CV$

Putting value, we get

$$Q = 100\times10^{-12}\times50$$

$$= 10^{2}\times10^{-12}\times5\times10$$

$$= 5\times10^{2-12+1}$$

$$= 5\times10^{-9}$$

$$Q = 5\times10^{-9}$$

$$= 0.005\times10^{-6}$$

$$= 0.005\ \mu c$$

EXAMPLE 15.4

Two capacitors of 5 μF and 10 μF capacitance are connected in parallel. What would be the equivalent capacitance? If a 20V battery is connected across the combination. Find out:

(L. B '10)

(i) The voltage across the two capacitors.

(ii) The quantity of charge on each capacitor.

Solution:

The given data is

$C_1 = 5\mu F = 5 \times 10^{-6} F$

$C_2 = 10\mu F = 10 \times 10^{-6} F$

$C_e = ?$

$V = 20 V$

As C_1 and C_2 are connected in parallel, so we use the following formula.

Formula:

$C_e = C_1 + C_2$

Putting values, we get.

$C_e = 5\mu F + 10\mu F$

$\boxed{Ce = 5\mu F}$

(i) To find voltage across the parall combination we used the characteristic of parallel combination that in such combination voltage across each capacitor is same. Hence voltage across each capacitor is equal to voltage of battery = 20V.

(ii) The charge stored on each capacitor is given by the following formula.

$Q = C V$

Putting values, we get

Charge stored on $Q_1 = C_1 v$

$= (5 \times 10^{-6}) \times 20$

$= 100 \times 10^{-6} c$

$\boxed{Q_1 = 100\mu C}$

Similarly, the charge stored on C_2 is given by

$Q_2 = C_2 V$

$= (10 \times 10^{-6}) \times (20 v)$

$= \boxed{200 \ \mu C}$

EXAMPLE 15.5

Capacitors of 3 μF and 6 μ F capacitance are connected in series. Find the equivalent capacitance.

Solution:

The given data is

$C_1 = 3\mu F = 3 \times 10^{-6} F$

$C_2 = 6\mu F = 6 \times 10^{-6} F$

$C_e = ?$

Formula:

$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2}$$

Putting value on R.H.S we get

$$= \frac{1}{3} + \frac{1}{6}$$

$$= \frac{6+3}{(6)\times(3)}$$

$$\frac{1}{C_e} = \frac{9}{18}$$

So $\boxed{C_e = 2\,\mu F}$ Ans

NUMERICAL PROBLEMS

15.1: The charge of how many electrons would be equal to 10 C?

Solution:

Number of electrons in 1 coulomb charge = 6.25×10^{18}

Number of electrons in $1\mu C = 6.25 \times 10^{18} \times 10^{-6}$

Number of electrons in $1\mu C = 6.25 \times 10^{12}$

Number of electrons in $10\mu C = 6.25 \times 10^{12} \times 10$

Number of electrons in $10\mu C = 6.25 \times 10^{13}$

15.2: Two point charge $q_1 = 10\mu C$ and $q_2 = 5\mu C$ are placed at a distance of 150 cm. Find the coulomb's force between them. What is the direction of this force?

Solution:

The given data is

$q_1 = 10\mu c = 10 \times 10^{-6}$ c

$q_2 = 5\mu c = 5 \times 10^{-6}$ c

$r = 150$ cm $= 1.5$m

$F = ?$

Formula:

$$F = \frac{1}{4\pi \in_o} \frac{q_1 q_2}{r^2}$$

Putting values we get.

$$F = \frac{(9 \times 10^9) \times 5 \times 10^{-6} \times 10 \times 10^{-6}}{(1.5)^2}$$

$$\frac{9 \times 5 \times 10^{9-6+1-6}}{2.25} = \frac{45 \times 10^{-2}}{2.25}$$

$$= 0.2N$$

$\boxed{F = 0.2N}$ Ans

This is force of repulsion between the two charges have same charge.

15.3: When a charge of +10μC is placed at a point, it experiences a force of 10^{-4} N. Find the value of electric intensity at this point.

Solution:

The given data is

$q = +10\mu C$

$= 10 \times 10^{-6}$ C

$F = 10^{-4}$ N

$E = ?$

Formula:

We know the formula of Electric field Intensity

$$E = \frac{F}{q}$$

Putting values, we get

$$E = \frac{10^{-4}}{10 \times 10^{-6}} = 10^{-4+6-1}$$

$\boxed{E = 10\ Nc^{-1}}$ Ans.

15.4: The value of a point charge is 500 µC. Find the electric intensity due to it at a distant of 50 cm from it. **(L. B '10)**

Solution:

The given data is

$q = 500\mu C$

$q = 500 \times 10^{-6}$ C

$E = ?$

$r = 50cm = 0.5m$

Formula:

$$E = \frac{1}{4\pi \in_o} \cdot \frac{q}{r^2} \qquad E = 9 \times 10^9 \times \frac{500 \times 10^{-6}}{(0.5)^2}$$

$$= \frac{9 \times 10^9 \times 5 \times 10^2 \times 10^{-6}}{0.25} = \frac{45 \times 10^{9+2-6}}{0.25}$$

$$= \frac{45 \times 10^5}{0.25}$$

$\boxed{E = 1.8 \times 10^7\ Nc^{-1}}$ Ans

15.5: The potential at a point in an electric field is 10^4 V. If a charge of +100µC is brought from infinity to this point. What would be the amount of work done on it?

Solution:

The given data is

$V = 10^4$ volts

$q = +100\mu C = 100 \times 10^{-6}C$

$W = ?$

Formula:

$$V = \frac{w}{q}$$

$$W = q \times V$$

Putting values, we get

$$W = (100 \times 10^{-6}) \times (10^{4})$$

$$= 10^{2} \text{ x } 10^{-6} \text{ x } 10^{4}$$

$$= 10^{6-6} = 10^{o} = 1$$

$\boxed{w = 1J}$ **Ans.**

15.6: The potential at a point in an electric field is 100V. If a charge of 750μC is placed at this point, what would be its potential energy?

Solution:

The given data is:

$V = 100$ volts

$q = 750\mu c = 750 \text{ x } 10^{-6}C$

P.E. = ?

Formula:

$$P.E. = qV$$

Putting values, we get

$$P.E. = (75 \times 10^{-6}) \times (100)$$

$$= 75 \times 10^{-6} \text{ x } 10^{2}$$

$$= 75 \times 10^{-4}$$

$\boxed{P.E. = 0.075J}$ **Ans.**

15.7: A point charge of +2C is transferred from a point at potential 100V to a point a potential 50V, what would be the energy supplied by the charge?

Solution:

The given data is

$q = +2C$

$V_1 = 100$ volts

$V_2 = 50$ volts

P.E. = ?

Formula:

$$P.E. = q\,(V_1 - V_2)$$

Putting values, we get

$$P.E. = (+2)\,(100 - 50)$$

$\boxed{P.E. = 100J}$ **Ans.**

15.8: The capacitance of a parallel plate capacitor is 50 pF. If this capacitor is charge by a battery of 12 V, what would be the charge stored in the capacitor?

Solution:

The given data is

Capacitance = $c = 50 \times 10^{-12}F$

Voltage = $v = 12$ volts

Charge stored = $Q = ?$

Formula:

$Q = CV$

Putting values, we get

$Q = (50 \times 10^{-12}) \times (12)$

$Q = 0.6 \times 10^{-9}$

$\boxed{Q = 0.6\ nC}$ **Ans.**

15.9: The capacitors of capacitance 5 μF and 10 μF are connected in parallel. Find the equivalent capacitance of the combination. If a battery of 10 V is connected across this combination, find the charge stored in each capacitor.

Solution:

The given data is

$C_1 = 5\ \mu F = 5 \times 10^{-6}F$

$C_2 = 10\ \mu F = 10 \times 10^{-6}F$

$V = 10$ volts

$Q = ?$

$C_e = ?$

The formula equivalent for equivalent capacitance in parallel capacitance is

Formula:

$C_e = C_1 + C_2$

Putting values, we get

$C_e = (5 \times 10^{-6} + 10 \times 10^{-6})$

$= (5 + 10) \times 10^{-6}$

$C_e = 15\mu F$

In case of parallel combination, the value of charge stored on each capacitor is calculated by using formula.

Formula:

$Q = CV$

Putting values, we get

$Q_1 = C_1 V$

$Q_1 = (5 \times 10^{-6}) \times (10)$

$= 50 \times 10^{-6}$

$\boxed{Q_1 = 50\mu c}$ **Ans.**

Similarly:

$Q_2 = C_2 V$

Putting values, we get

$Q_2 = (10 \times 10^{-6}) \times (10)$

$Q_2 = 100 \times 10^{-6} c$

$\boxed{Q_2 = 100\mu c}$ **Ans.**

15.10:Two capacitors of capacitance 6 μF and 2 μF are connected in series. Find the equivalent capacitance of the combination. If a 12V battery is connected across this combination. Find the charge and the potential difference across each capacitor.

Solution:

The given data is

$C_1 = 6 \times 10^{-6}$ F

$C_2 = 12 \times 10^{-6}$ F

$C_e = ?$

V = 12 volts

Q = ?

P.d = ?

Formula:

The formula to calculate equivalent capacitance for capacitors in series is

$$\frac{1}{C_e} + \frac{1}{C_1} + \frac{1}{C_2}$$

Putting values, we get

$$\frac{1}{C_e} = \frac{1}{6} + \frac{1}{12}$$

$$\frac{1}{C_e} = \frac{12+6}{12 \times 6}$$

$$\frac{1}{C_e} = \frac{1}{4}$$

$\boxed{C_e = 4\mu F}$ **Ans.**

Formula:

$Q = C_e V$

Putting values, we get

$Q = 4 \times 10^{-6} \times 12$ volts

$Q = 48 \times 10^{-6}$

$Q = 48 \times 10^{-6}$

$\boxed{Q = 48\mu C}$ **Ans.**

Formula:

$$V = \frac{Q}{C}$$

Putting, we get

$$V_1 = \frac{Q}{C_1} = \frac{48 \times 10^{-6}}{6 \times 10^{-6}}$$

$\boxed{V_1 = 8 \text{ volts}}$ **Ans.**

$$V_2 = \frac{Q}{C_2} = \frac{48 \times 10^{-6}}{12 \times 10^{-6}}$$

$\boxed{V_2 = 4 \text{ volts}}$ **Ans.**

MULTIPLE CHOICE QUENSTIONS

Q. Circle the correct answer.

1. Charge can be produced by:
- a) combing in hair
- b) rubbing glass rod on silk
- c) by rubbing ebonite on wool
- d) all of these

2. Negative charge is produced by rubbing:
- a) ebonite rod on wool
- b) glass rod on silk
- c) ebonite road on silk
- d) ebonite rod on glass rod

3. By rubbing glass rod on silk there is deficiency of_____ on glass rod:
- a) Protons b) electrons
- c) Neutrons d) no change

4. In normal condition, solid body is:
- a) positively charged
- b) negatively charged
- c) neutral
- d) none

5. Solid bodies are charged by:
- a) loosing electrons
- b) by taking electrons
- c) both a, b d) none of these

6. If a solid body accepts electrons it is Charged:
- a) positively b) negatively
- c) neutral d) none

7. If a solid body looses electrons it is charge:
- a) positively b) negatively
- c) neutral d) none

8. In the last orbit electrons are under less force of attractions of:
- a) protons b) neutrons
- c) positron d) nucleus

9. In the electroscope there are leaves of:
- a) aluminum b) brass
- c) gold d) platinum

10. If a neutral body brought near to the electroscope its leaves:
- a) diverge b) contract
- c) shut d) remain in normal position

11. If a negatively charged body brought near to the electroscope its gold leaves will have:
- a) Negative charge
- b) positive charge
- c) natural d) none of these

12. To make electroscope positively charge body will touch to the disc:

a) positively charge
b) negative
c) neutral d) charge

13. If a charge body will brought near to the negatively charge electroscope and divergence of leaves is more then the body has:

a) same charge b) charge
c) neutral d) none of these

14. With the help of electroscope we can find that a body is:

a) conductor b) insulator
c) charged d) all of these

15. If there is divergence of leaves by touching a body with electroscope then the body is:

a) charged b) neutral
c) no charge d) insulator

16. If there is no divergence in the leaves by touching the body with electroscope then body is:

a) Charged b) Insulator
c) Negative d) Positive charge

17. One coulomb charge has ______electrons:

a) $6.25x10^{18}$ b) $6.25x10^{15}$
c) $6.25x10^{14}$ d) $6.25x10^{12}$

18. The force of attraction or repulsion between charged bodies can be studied by the law:

a) Dalton b) Newton's
c) Coulomb's d) Einstein

19. In system international the unit of charge is:

a) ampere b) joule
c) volts d) coulomb

20. In the Sl, the unit of electric potential is:

a) ampere b) joule
c) volt d) none

21. If the field is stronger then lines of force are to each other:

a) far away b) separated
c) closer d) no effect

22. If the potential energy of one coulomb charge is one joule then its potential will be:

a) one volt b) 2volts
c) 3 volts d) 5 volts

23. Chemical battery was invented by:

a) Ampere b) Alexandro Volta
c) Watt d) Newton

24. Chemical battery was invented in:

a) 1775 b) 1774
c) 1778 d) 1776

25. The product of charge 'q' and potential difference is equal to:

a) power b) force
c) work d) energy

26. The unit of capacitance is:

a) volt b) Ampere
c) farad d) Joule

27. ______ is used as a di-electric between two plates:

a) wire b) air
c) metal d) Conductor

28. The capacitance of a capacitors is by joining them in series:

a) Increased b) same
c) decreased d) none

29. The capacitance of a capacitors is by joining them in parallel:

a) Increased b) much less
c) decrease d) no change

30. Examples of fixed capacitors are:

a) paper capacitor
b) mica capacitor
c) both a , b d) none of these

31. In variable capacitor dielectric used is:

a) paper b) plastic
c) mica d) air

32. In fixed capacitor dielectric used is:

a) paper b) metal
c) mica d) a and c

33. Variable capacitors are used in

a) Transmitter b) transmitter coil
c) radio sets d) regulators

34. Device used to store electric charge is called: ***(Lahore Board 2006)***

a) electroscope b) conductor
c) capacitors d) capacitance

35. If the distance between two charge is 20cm and if this distance is reduced 10cm, then coulomb force is:

a) half b) 2 times
c) $1/4^{th}$ d) 4 times

36. Two opposite charges of 500μ C and 100μC are placed at a distance of 0.5cm then force of attraction between them is:

a) 1800N b) 1900N
c) 1850N d) 1880N

37. One μF =

a) 10^{-5}F b) 10^{-6}F
c) 10^{-10}F d) 10^{+12}F

38. One pico F =

a) 10^{-12}F b) 10^{-10}F
c) 10^{-11}F d) 10^{+12}F

39. When a positive charge of 2 coulombs is placed at a point in an electric field, it experiences a force of 6N. The intensity of electric field at this point is:

a) 6 Nc^{-1} b) 3 Nc^{-1}
c) 12 Nc^{-1} d) 1.5 Nc^{-1}

40. In electrostatic the value of K is 9 x 10^9:

a) Nm^2c^{-2} b) N^2mc^{-2}
c) $Nm^{-2}c^2$ d) Nm^2c^2

41. In electrostatic all charges are in: **(L. B '10)**

a) The same direction
b) Opposite direction
c) Motion d) Static

42. Capacitor is a device, which is used to store:

a) Power b) Current
c) Charge d) None

ANSWERS

1.	d	**2.**	a	**3.**	b	**4.**	c	**5.**	c	**6.**	b	**7.**	a
8.	d	**9.**	c	**10.**	d	**11.**	a	**12.**	a	**13.**	a	**14.**	d
15.	a	**16.**	b	**17.**	a	**18.**	c	**19.**	d	**20.**	c	**21.**	c
22.	a	**23.**	b	**24.**	d	**25.**	d	**26.**	c	**27.**	b	**28.**	c
29.	a	**30.**	c	**31.**	d	**32.**	d	**33.**	c	**34.**	c	**35.**	d
36.	a	**37.**	b	**38.**	a	**39.**	b	**40.**	a	**41.**	d	**42.**	c

GIVE SHORT ANSWER

Q.1: How positive charge is acquired?

Ans. When a body looses electrons, then it acquires positive charge.

Q.2: How negative charge is acquired?

Ans. When a body accepts electrons, then, it acquires negative charge.

Q.3: What is electroscope?

Ans. It is an instrument which is used to detect the presence and nature of charge on a body.

Q.5: What is the process of ionization?

Ans. When a body acquires charge, then, it is called charged body and its atom becomes ionize which may be positive or negative.

Q.6: What is coulomb's law? Also write its mathematical form.

Ans. The force of attraction or repulsion between two charges is directly proportional to the product of charges and is inversely proportional to the square of distance between them

$$F = K\frac{q_1 q_2}{r^2}$$

Q.7: What is meant by electric field?

Ans. The region around the charge at which effect of another charge can be felt is called electric field.

Q.8: Define electric intensity.

Ans. The strength of field at any point is called electric intensity or the force per unit charge is called electric intensity. Its unit is N/C.

Q.9: What are electric lines of force and what do they tell us?

Ans. The direction of electric intensity in an electric field can be indicated by drawing tangents. These lines are called electric lines of forces. These lines of force tell us about the direction of electric intensity and strength of field.

Q.10: What is meant by electric potential?

Ans. The potential at any point in the field is defined as, the potential energy of unit positive charge in bringing the charge from infinity to that point in an electric field.

$$V = \frac{W}{q}$$

Q.11: Define volt.

Ans. If potential energy of one coulomb positive charge placed at a point is one joule, then, its potential is said to be 1 volt.

Q.12: Why the tyres of aeroplane are made of conducing rubber?

Ans. During flight of aeroplane its body is charged. Its tyres are made of conducting rubber so that during landing, its charge can easily transfer to earth.

Q.13: Define electrostatic induction. (L. B '10)

Ans. In the presence of charge body if one end of charged body has like charges at one end and unlike charges at the other end of an insulated conductor.

Q.14. Write the application of electrostatic induction.

Ans. The phenomenon is used to separate the smoke and other particles coming out of the chimneys of factories and also used in applying paint on the surfaces.

Q.15. What is capacitor?

Ans. It is a device used to store charge is called capacitor.

Q.16. Explain the structure of a simple capacitors.

Ans. It consists of two metal plates, which are parallel, and an insulating sheet is placed between them, which is called dielectric.

Q.17. Write the types of capacitor and define the unit of capacitance.

Ans. There are two types (i) variable capacitors (ii) fixed capacitors. The unit of capacitance is farad. The capacitance of a capacitor is one farad, if one coulomb charge stored under the potential difference of 1 volt.

Q.18. What is parallel combination of capacitor? Write its advantages.

Ans. In this combination capacitors are joined in such way that all the left plates of capacitor are connected at one point and all the right plate at other point is called parallel combination. In this case capacitance of the capacitor will increase.

Q.19. What is series combination? Write its advantage.

Ans. When capacitors are joined together in such a way the left plate of one capacitor is connected with the right plate of other capacitor, then, in this case capacitance will decrease.

Q.20. Why fixed capacitors are called fixed?

Ans. Because their capacitance cannot be changed, since these plates are immoveable, they are called fixed capacitors.

Q.21. What are variable capacitors. Where they are used?

Ans. The capacitance of a capacitor can be changed because its plates are moveable. So these capacitors are called variable capacitor. The variable capacitors are used for tuning in radio sets.

Q.22. A point charge Q is placed in front of plane metallic plate as show in the figure draw the lines of force.

Ans.